Water Well Disinfection Manual

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Acknowledgements

This manual is the product of contributions from numerous individuals interested in providing information on the disinfection of onsite water supplies to well drilling contractors, environmental health professionals and others. Without their willingness to share information, experiences, time, and expertise, this manual would not have been possible.

<u>Special thanks to:</u>

Kalamazoo County (Michigan) Water Well Disinfection Work Group Members, including water well drilling contractors Dick Clark, Sandy Slevatz, Mike Smith, and Miles Foune, and Environmental Sanitarians Deborah Werner, Bill Speeter, and Heidi Wines from the Kalamazoo County Human Services Department.

Individuals who took the time to review and comment on drafts of this manual, including John Schnieders, Stuart Smith, Neil Mansuy, Dr. Roy Cullimore, Alan W. Coombs and environmental health professionals from the Michigan Department of Environmental Quality, Water Division, including Anita Ladouceur, Joseph Crigier, James McEwan, and John Chickering.

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July 2003

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Natural ground water from all but very shallow aquifers is considered free from pathogenic (disease causing) bacteria and viruses (Bouwer, 1984). As such, ground water obtained from properly designed and constructed water wells is generally free of disease causing bacteria, and continuous disinfection is unnecessary (Roscoe Moss Company, 1990). However, disinfection of a new or repaired water supply system is needed to remove contaminants introduced during the construction or repair process (Driscoll, 1986). Existing water supplies require disinfection when routine maintenance of the system takes place, or when the results of water samples show the presence of coliform bacteria (Driscoll, 1986). This manual provides information to water well drilling contractors, local health department (LHD) sanitarians, and others involved in potable water system construction, operation, or evaluation.

Disinfection is the inactivation or destruction of pathogenic organisms through the disruption of the organisms' normal life processes (Connell, 1996). Disinfection does not mean sterilization. The result of effective disinfection is the production of potable, or drinkable, water. Throughout this manual the authors promote the concept that "disinfection," when applied to water well system construction, should be considered from a broader perspective than merely the application of chemicals to achieve microbial inactivation. Disinfection is a process that includes the following components:

1. Proper water supply system preparation, including the sanitary completion of the water well, the cleaning of existing wells, and the proper development of new wells.
2. Thorough flushing of the water supply.
3. Treatment with a properly prepared chlorine solution.
4. Collection and analysis of water samples.

Although there are several chemical disinfectants that may be used to treat a well, this manual only addresses the use of chlorine, the most commonly used water supply disinfectant.

When a new water well is drilled or an existing water well or household piping is repaired, bacteria can be introduced into the water system (Campbell, et al., 1973). Many state construction codes (for example, Part 127, 1978 PA 368, as amended, Michigan's Water Well Construction and Pump Installation Code) require disinfection of a new or repaired water system before it is placed into service. Treatment with chlorine, combined with proper well preparation and flushing, usually eliminates the bacteria. Water well drilling and pump installation contractors are responsible for disinfecting the work they perform. Once a properly constructed water well has been properly disinfected, it should produce safe water consistently without the need for continuous chlorination.

The bacteria used as an indicator of contamination are coliform organisms, normally found in the intestine and feces of warm-blooded animals. Their presence in the water supply indicates a serious potential for illness-causing bacteria or viruses to be present. If a water sample from a new, repaired, or existing well is positive for coliform bacteria, an immediate repeat sample is an essential step to confirm the risk. Consuming water with coliform bacteria is not recommended and appropriate advisories should be issued to persons who use the water system.

A positive coliform water sample does not always mean that the water well itself is contaminated. The well could be producing coliform-free water while a bacteria problem exists in the household plumbing. Collecting water samples from different points can then help pinpoint the location of the problem.

Disinfection should be performed by a licensed water well drilling contractor. While water well owners may legally disinfect their own wells, they should have a working knowledge of water system construction and be aware of electrical hazards before attempting such work. Improper action could damage the water system or result in injury or death.

WELL PREPARATION – NEW WELLS

There are two elements that are essential for the effective disinfection of newly constructed water wells:

1. Preventing the introduction of contaminants into a well during construction by employing sanitary drilling practices.
2. Proper well development to remove drilling fluids and drill cuttings from the aquifer.

SANITARY DRILLING PRACTICES

The introduction of microbial contaminants (including coliform and E. coli bacteria) into newly constructed or repaired wells can be minimized by practicing good general sanitation during storage, transport, handling, and installation of well components.

Proper sanitation refers to cleanliness and taking precautions to prevent disease by not introducing bacteria and other contaminants while installing or repairing a water supply system. When the drilling contractor takes precautions to prevent the unnecessary introduction of contaminants into the well, the task of disinfecting the well becomes much easier.

The sanitary practices in this section were offered by Michigan well drillers who have implemented these practices to minimize the frequency of positive coliform water samples collected from newly constructed water wells.

Storage and Transportation of Well Components and Drilling Supplies
Good sanitation by the contractor starts at the shop and is important during the trip to the drilling site. The organization and storage of materials and equipment will benefit the contractor during the installation and final disinfection of the completed water supply system.

1. **General**
   a. Water supply equipment and construction materials should be stored off the ground on racks or shelves, indoors whenever possible. This will help avoid the risk of contamination by soil, dust, birds, mice, insects, and other contaminants.

***Store materials off the ground and indoors when possible*.**

   b. Keep equipment storage areas on transportation vehicles clean.
   c. During transport keep equipment and materials covered to prevent contamination from insect splatter, roadway dirt, and exhaust fumes.

Clean well component storage

If a component is wrapped, boxed, or otherwise protected when received, leave these protective coverings on until just before use.

2. **Specific recommendations.**
   a. Well casing. Keep end caps on well casing whenever possible. The male end of steel casing is generally capped to protect the threads, but the capping of both ends of all well casing would exclude the risk of external contamination by preventing the entry of vermin, dirt, and other contaminants.
   b. Well Screen If the screen has a protective wrap, do not remove it until ready for use.
   c. Pumps. Do not remove the pump's shipping box until the pump is ready to be installed.

Keep pumps in shipping boxes until time of installation.

   d. Drop Pipe. Protect openings at the end of the pipes. Most of the flexible plastic drop pipe is crimped on both ends to prevent contamination. Most rigid PVC pipe is capped only on the male threaded end.

Keep the ends of pipes capped or crimped until ready for use.

Drilling Equipment and Techniques

Drilling a well creates a pathway from the ground surface to the source of the drinking water (aquifer). Soils at or near the ground surface are populated with extremely high numbers of bacteria, viruses, protozoa, and other microorganisms. Larger organisms such as earthworms, millipedes, slugs, snails, and insects also inhabit soil zones and are a source of bacterial/viral contamination. Preventing contaminants from entering the drinking water source will greatly improve the chances of successfully disinfecting the well.

1. **Cleaning and Sanitizing Drill Bits, Mud Pans, and Other Drilling Equipment**
   a. A sufficient volume of chlorinated water should be at the drill site for pressure spraying of equipment and well components that will come into contact with the source water (Driscoll, 1986).

High pressure washing of drilling tools.

b. Spray down tool bits, mud pans, auger flights, and drill rods both before and after drilling (Kazmann, 1986).

2. **Drill Water**

a. Water used during the well drilling process must come from an approved potable water supply source. Surface water from ponds, lakes, rivers, or ditches, may contain disease causing organisms, and its use for water well drilling is prohibited by the state well code.

b. The drill water must have a minimum chlorine residual of 10 ppm. The chlorine residual will help suppress the growth of bacteria.

Maintain a chlorine residual.

Transport in clean containers.

c. The drill water must be transported in a clean, sanitary container. Water transport tank outlets should allow for complete drainage of the tank.

d. Water trucks/tanks should be cleaned occasionally to remove accumulated debris and mineral deposits.

3. **Rig Operator Practices**

a. Remember to keep everything clean that will come into contact with the water-producing zone.

b. The ground surface contains high levels of bacteria and other microorganisms. Keep well components and drilling equipment off the ground when possible.

c. Do not drag well casing along the ground. Keep dirt out of pipe threads.

d. Keep the well screen off the ground.

e. Do not contaminate the drilling mud. The mud slurry is circulating back down the borehole and has the potential to carry contaminants introduced into the mud pan. Therefore, do not step into, spit, or place contaminants into the mud pan (Lehr, et al., 1988) (Chapelle, 1993).

f. Do not use drilling fluid additives consisting of Guar gum or starch products. These additives can act as a nutrient for bacterial growth and make well disinfection extremely difficult.

g. Avoid the use of excessive amounts of lubricant (grease) on drill rods. A glob or a mere film of grease on the inside of the well casing can protect bacteria from exposure to disinfectants (Driscoll, 1986) (Campbell, et al., 1973).

h. Avoid handling well components with dirty or greasy hands or gloves.

i. Wipe off any well components that inadvertently become soiled.

4. **Filter Packs**

a. Keep bagged filter pack material stored and transported in a clean, dry manner.

b. The purchase and storage of bulk filter pack material should be avoided because of the potential for the contamination of the exposed material. If use of bulk filter pack material is necessary because of the large amount to be used, keep it covered and on a cement pad or other clean, flat surface. This will help prevent contamination of the filter pack material by soil, dust, animal droppings, etc.

c. Disinfect the filter pack material before placement in the well (Roscoe Moss Company, 1990) (Driscoll, 1986). Either saturate the filter pack material with a chlorine solution before placement, or add granular calcium hypochlorite to the filter pack as it is poured into the well at ¼ cup of chlorine per 50 pounds of filter pack. Do not use chlorine tablets.

WELL DEVELOPMENT

For new or rehabilitated water wells, adequate development is essential if the disinfection process is to be successful. During the construction of a well, drill cuttings and drilling fluids may accumulate in the well and the geologic formations surrounding the well. If not removed, these materials may interfere with the production capabilities of the well and can provide a location for coliform bacteria to reside. Proper development of the well facilitates removal of these materials, which increases the success rate of the disinfection stage.

Material Removal by Well Development

<u>Turbidity:</u> Well water must be free of turbidity. Suspended particles in turbid water interfere with the chlorine's efforts to make contact with and kill microorganisms (LeChevallier, et. al., 1981). The turbidity is normally residuals of drill cuttings and/or drilling fluids that have been pushed out into the formation surrounding the borehole during the well construction process. Drilling fluid used in constructing bore holes for wells contain substantial numbers of microorganisms(Lehr, et. al., 1988). The drilling process, therefore, inoculates any aquifer system being drilled (Chapelle, 1993). If not removed during the development phase of construction, bacteria that are trapped in these materials become lodged and may migrate toward the well as the well is pumped, resulting in positive coliform tests. Removal of cuttings and drilling fluids improves permeability and enhances the ability to flush more water, which helps remove contaminants.

<u>Mud Cakes:</u> For water wells drilled using the mud rotary method, a mud cake is formed on the sidewall of the borehole. Drilling fluid bentonites and drilling solids are the main components of the mud cake, and are not themselves considered a contamination source. However, during the construction of the well, the drilling fluids are likely to become contaminated with coliform bacteria as they are circulated. As such, the portion of the mud cake that exists around the well screen must be broken down and removed during development of the well. If not removed, the mud cake may interfere with the chlorination process and be the cause of positive coliform test results.

Well Development Includes Surging, Agitation, and Pumping to Waste

The entire length of the exposed borehole (open rock or around the screen) must be surged and agitated during the well development process (Driscoll, 1986). This loosens and aids in the removal of drilling fluids and cuttings that have invaded the formation and are trapped there. Development also breaks up and removes the mud cake. Simple pumping of the well is not as effective as surging/agitation to remove these contaminants. After being properly surged and agitated, the well needs to be pumped to waste to help flush any remaining residuals of drilling fluids from the well. Additives are available to aid removal of the mud cake and drilling fluid residue.

Well Development Objectives (Driscoll, 1986)

1. Repair damage done to the formation by the drilling operation.
2. Alter the basic physical characteristics of the aquifer near the borehole so that water will flow more freely to the well.
3. Reduce compaction and intermixing of grain sizes produced during drilling by removing fine material from the pore space.
4. Increase natural porosity and permeability of the previously undisturbed formation near the well bore by removing fines.
5. Remove the filter cake or drilling fluid film that coats the borehole.
6. Remove much or all of the drilling fluid and natural formation solids that have invaded the formation.
7. Create a graded envelope of sediment around the screen in a naturally developed well, stabilizing the formation so that the well will yield sand-free water.

Factors That Affect Development (Driscoll, 1986)

1. **Well Completion Method**
   a. Natural Development. Highly permeable zone created around the screen using materials existing in the formation.
   b. Filter Packing. Specially graded sand or gravel is placed in the annulus between the screen and the natural formation.

2. **Screen Open Area and Slot Configuration.**
   a. Screen open areas vary
      - Perforated pipe as low as 1 percent
      - Continuous slot wire wound 40 percent or more
   b. The more open area, the more efficient the development – development energy can reach further into the formation.

3. **Slot Size**
   a. Select a slot width that retains about 40 percent of sediment in the formation.
   b. Removal of too much sediment may cause settling of overlying surface materials.
   c. If well screen openings are smaller than necessary, full development may not be possible.

4. **Drilling Fluid Type**
   a. All drilling fluid must be removed from both the borehole wall and the formation.
   b. Rate and effectiveness of drilling fluid removal depends not only on the type of additive used, but also on the physical characteristics of the aquifer, the depth of the well, and the drilling fluid viscosity, density, and filtration control.

5. **Filter Pack Thickness**
   a. The filter pack reduces the amount of development energy reaching the formation.
   b. The thinner the filter pack, the easier it is to remove undesirable fine sand, silt, and clay.
   c. Filter packs should normally not be thicker than 8 inches and must be properly sized and graded.

6. **Type of Formation** - Different types of formations require specific development methods that are best suited for that formation.
   a. Highly stratified coarse grain deposits require methods that concentrate energy on small parts of the formation.
   b. Uniform deposits need methods that apply powerful surging forces over the entire borehole.

Well Development Methods (Driscoll, 1986)

1. **Overpumping** - Pumping at a higher rate than the well will be pumped when put into service. The well is pumped until it is ***free of sand and turbidity***.
   Most development action takes place in the most permeable zones closest to the top of the screen.
   a. The longer the screen, the less development in the lower part of the screen.
   b. Water flows in only one direction. May cause bridging of sand particles – formation only partially stabilized.
   c. The permanent pump should not be used. Using a customer's permanent pump may lead to excessive wear due to sand pumping.

2. **Backwashing** - A surging action consisting of alternately lifting a column of water above the pumping level and then letting the water fall back into the well.
   The pump is started, water is lifted to the surface, the pump is shut off, and water in the pump column pipe falls back into the well.
   a. The well must periodically be pumped to waste to remove sand that has accumulated inside the screen.

b. The process is repeated until the well is free of sand and turbidity**.**
c. The surging effects may be concentrated only near the top of the screen or in the most permeable zones.
d. Lower parts of the screen may be undeveloped.
e. Effectiveness in high capacity wells is relatively limited.

3. **Mechanical Surging** - Forcing water to flow in and out of a screen by operating a plunger up and down in the casing.
    a. The plunger is usually called a surge block, surge plunger or swab.



Typical Surge Blocks

    b. The force exerted on the formation depends on the length of the stroke and the vertical velocity of the surge block.
    c. Before starting, bail the well to make sure water will flow into it.
    d. Lower the surge block into the well until it is 10-15 feet beneath the static water level, but above the screen.
    e. The initial surging motion should be gentle.
    f. As water begins to move more easily, both into and out of the screen, the surge block is lowered in steps to just above the screen.
    g. As the block is lowered, the force of the surging is increased.
    h. If the well has a long screen, the surge block may need to be lowered into the screen to develop the lower portions of the screen.
    i. Surging action continues for several minutes, then the surge block is removed.
    j. Compressed air, a bailer, or a sand pump is then used to remove accumulated sediment.
    k. Continue surging and cleaning until little or no sand can be pulled into the well, and the water is free of turbidity.
    l. Mechanical surging produces good results for screen installations in zones having good porosity and hydraulic conductivity.


Well development using a surge block.

4. **Air Development by Surging and Pumping** - The practice of developing a well using air to alternately surge and pump the well. Commonly used surging methods are air lift surging and air burst surging.
    - Air development procedures should begin by determining that ground water can flow freely into the screen. Application of too much air volume in a borehole when the formation is clogged can result in a collapsed screen.
    - Initially, keep the air line up in the casing and pump at a moderate rate to minimize collapse pressures on the screen.

a. **Air lift surging**

- Air is injected into the well to lift the water to the surface.
- As water reaches the top of the casing, the air supply is cut off, allowing the water column to fall.
- Falling water surges back into the formation.
- Surging in this manner continues for several minutes.
- Periodically, air lift pumping is used to remove sediment from the screen or borehole.
- These surging cycles continue until the water is relatively free of sand and turbidity.

b. **Air burst development** - A combination of pumping with air and using large bursts of air injected into the screen or rock borehole to surge the formation.

- After uninhibited flow into the screen has been established, lower the air line to near the top of the screen.
- Then pump with air at a reduced rate.
- Continue pumping until water is virtually sand free.
- The valve at the air tank outlet is then closed, allowing pressure in the tank to build.
- Allow sufficient pressure to build up in the air tank (approximately 43 pounds per square inch [psi] for each 100 feet of submergence).
- Surging is then initiated by quickly opening the air valve, allowing air from the tank to rush suddenly into the well. This drives water outward through the well screen openings.

- Ordinarily, a brief but forceful head of water will also overflow or shoot from the casing at the ground surface.
- After the charge of air has been released, the air lift pumping will start again, reversing the flow (water flows into the well), completing the surging cycle.
- The well is pumped until the water clears up, and then another "head" of air is released.
- These surging cycles continue until the water is relatively free of sand and turbidity immediately after the screen has received an air blast.

5. **High Velocity Jetting** - Consists of operating a horizontal jet of water or air inside the well screen so that high velocity streams of water shoot out through the screen openings. The jetting energy agitates and rearranges the particles in the formation.

a. Jetting tool is placed near the bottom of the screen and rotated slowly while being pulled upward at a rate of 5 to 15 minutes per foot of screen.

b. Material loosened from the formation accumulates in the screen as the jetting tool is raised.
c. Material is removed by airlift pumping or bailing.
d. Several passes may be needed to remove loosened sediment from the formation.
e. Process continues until sediment accumulation in the screen is negligible, and water from the well is relatively free of sand and turbidity.
f. Particularly successful in developing highly stratified unconsolidated formations.

g. The filter cake deposited on the borehole wall in conventional rotary drilling is effectively broken down and dispersed so the drilling fluid that has penetrated the formation can be pumped out.
h. In general**,** 200 psi at the nozzle for metal screens, and 100 psi for plastic screens.
i. Efforts should be made to limit sediment concentration in jetting water. Sediment causes abrasion damage to both jetting tools and screens.

Typical jetting tools



6. Rock Well Development.

a. In hard rock formations, such as limestone and granites, all drilling methods cause some plugging of fractures and crevices.
b. In softer formations such as some sandstones, the borehole wall may become plugged with finer material.
c. Cable tool - Bit action chips and crushes the rock and mixes it with water to form a slurry. The pounding of the bit forces some of the slurry into the openings in the rock.
d. Rotary - If drilling fluids are used in rock drilling, they may plug openings in the rock. Even air drilling methods can blow large quantities of fine material into the openings in the rock.
e. Any material that clogs openings in the rock must be removed by a development procedure.
f. Pumping alone may sometimes remove sediments from openings in the rock.
g. Surging or other means of development may be needed to obtain maximum capacity.
h. Pumps, airlines, surge blocks, etc., must be moved as needed to effectively expose the entire length of the open borehole to the development energy.

A common theme for each development method listed above is that the development of the well continues until the water coming from the well is free of sand and turbidity. This is essential for successful disinfection of the well.

WELL PREPARATION – EXISTING WELLS

Often the investigation of a water supply system contaminated with coliform bacteria will show that coliform bacteria are coming directly from the well. In these cases, the water well needs to be disinfected. However, the well must be properly prepared before disinfection. Debris in the bottom of the well, scale on the sidewalls of the casing, and slime buildup from biofouling organisms can interfere with the effective disinfection of the well. Barriers such as mineral scale or biofilm can limit the ability of chlorine to penetrate such barriers and reach the sheltered organisms, regardless of the concentration of hypochlorous acid or hypochlorite ion (Coombs, 2001).

Existing Well Construction Deficiencies or Problems
Evaluation of the sanitary integrity of the water well should be done before any attempt is made to disinfect the water supply system. The deficiencies or problems that may lead to contamination of the well include, but are not limited to:

1. **Buried Wellhead.** Buried wellheads are typically equipped with a compression-type well seal. Over time the gaskets in the seals begin to leak and contaminated water from near the ground surface can enter the well. In addition, the well is not easily accessible for repair. When the wellhead is exposed for any purpose, the casing should be extended to at least 12 inches above grade, and the wellhead equipped with an approved well seal or cap and a pitless adapter provided.

Buried well seal

2. **Unprotected Suction Line.** Any piece of pipe buried in the ground can develop leaks through mechanical damage or corrosion. A buried unprotected suction line from a well pump can allow contaminants to enter the water supply when the pump operates, sucking contaminants into the water supply. When an unprotected suction line is encountered, it should be replaced with a suction line that is protected with outer concentric piping. Converting jet pump systems to submersible pumps is also a means of eliminating buried suction lines.

Pumps with unprotected suction lines.

3. **Old Style or Damaged Well Cap**. Well caps that set on top of the casing and are secured by set screws or similar devices are generally not vermin-proof. Insects or other vermin may enter the well through the opening between the casing and the overlapping portion of the cap. Similarly, damaged well caps (such as those shown below) can allow rainwater, bird droppings, and other contaminants to enter the well casing. When damaged or older style well caps are encountered, they should be replaced with approved weather and vermin proof caps.

Damaged well caps

4. **Deteriorated or Damaged Casing.** Any opening in the casing caused by mechanical damage (e.g., hit by snow plow or other vehicle or damaged by vandalism) or corrosion may allow contaminants to enter the well. Damaged casing should be replaced, or the well should be properly plugged and a new well installed.

Cracked casing

Old dug well

5. **Unapproved Well Construction (less than 25 feet deep, crock well, short casing, etc.)** Any well that has been constructed in such a manner that contaminants from near the ground surface may enter the water supply should be plugged and replaced with a properly constructed well.

6. **Abandoned Wells on the Site.** Abandoned wells that have not been properly plugged provide a means for contaminants from near the ground surface to enter the ground water. An unplugged abandoned well can result in contamination of nearby water wells. Abandoned wells must be plugged using approved materials and methods.

Unplugged abandoned wells

7. **Openings in Electrical Appurtenances Such as Conduit or Junction Boxes.** Broken seals, unsecured conduit with ends exposed, or damaged electrical appurtenances provide access points for rain and/or insects to enter the water supply. These unprotected openings must be sealed when discovered.

Junction box on well cap and unsealed electrical conduit.

Yard hydrant – Potential cross connection

8. **Cross Connections with Contamination Sources** (such as an unapproved water supply tied in series with the well and stop and waste yard hydrants). Cross connections provide a means for the backflow or backsiphonage of contaminants into the water supply. Cross connections must be eliminated by installing approved cross connection control devices.

If well construction deficiencies are not corrected, treatment of the water well with chlorine may be a futile exercise, as the well may again become contaminated because of the defect.

Unapproved source of water.

Insect infested cap

Well Caps/Seals

If an old style well cap (not insect proof) is present or if the cap is damaged, insects may have entered the well and the bottom of the well may need to be flushed and disinfected. This condition is aggravated if the wellhead is surrounded by vegetation (bushes, tall plants, etc.), which attracts insects. Vegetation should be cleared away from the wellhead.

Old style cap located under a bush

Well Vents

Well caps or seals on a well equipped with a submersible pump are normally provided with a vent opening to allow the movement of air in and out of the casing as the well's water level fluctuates with pump operation. The vent helps prevent the formation of a partial vacuum inside the casing, which can enhance the potential for contaminant entry through leaking joints, corrosion formed holes in the casing wall, or other entry points (Joyce, 1982). If a well with a history of coliform bacteria contamination does not have a proper casing vent, one should be provided. A vent should be pointed downward, screened, and properly sized to allow sufficient air movement.

The movement of atmospheric air into the well is not normally considered a possible source of coliform bacteria contamination. However, the University of Wisconsin, in cooperation with the Wisconsin Department of Natural Resources, conducted a study (Trest, et al., 2001) investigating the possibility of air borne contaminants entering a well. The study suggested a possible link between air movement into a well casing and coliform bacteria contamination. The study concluded that conditions surrounding the wellhead location may play a role in whether coliform bacteria were detected in air samples. Conditions that influenced the likelihood of finding aerosolized coliform bacteria include:

- The presence of pet or fecal material close to the well
- Vegetation surrounding the wellhead.
- Recent lawn mowing around the well.
- During and within three hours after precipitation.

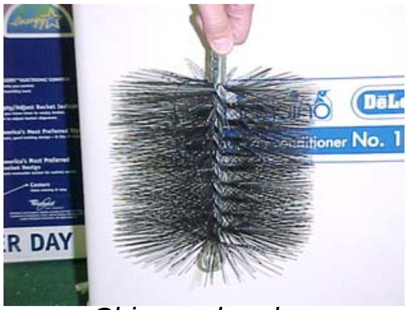
These conditions should be considered when trying to determine the source of a well's contamination.

Well Cleaning

The accumulation of scale and other debris on the sidewalls of the casing or in the bottom of the screen/borehole may "use up" available chlorine or protect bacteria from exposure to a chlorine solution. In these cases, the well should be cleaned and flushed before starting the chemical treatment phase of the disinfection process. Cleaning of the well may include:

1. “Scrubbing” the sidewall of the casing with a swab, packer, brush, or similar device.

Typical packers and seals used to clean the inside surfaces of well casing.



Chimney brush

Grinding brush

Brush made from wire cable

Typical brushes used to scrub the inside surfaces of well casing.

2. Removing debris from the bottom of the screen/borehole with an air line, bailer, or other method.

3. Pumping the well to waste to remove suspended materials in the water is essential, since these suspended materials interfere with the effectiveness of the chlorine (LeChevallier, et al., 1981). The suspended materials can bind up with or use up available chlorine resulting in less chlorine being available for disinfection. The water well should be pumped until the water is clear. Lower the pump to as close to the bottom of the well as possible during the pumping period.

WELL FLUSHING

Flushing is the process of using the scouring action of moving water to help rid a water supply of contaminants. Flushing is an essential part of the disinfection process (Schnieders, 2001). Flushing normally takes place several times during the disinfection process.

- ✓ Flushing is a normal part of the development of a newly constructed well and the preparation of an existing well before chlorine treatment.
- ✓ Flushing a water supply after treatment with chlorine is required to remove the chlorine residual from the well.

Pump Location When Flushing
Install the pump as close to the bottom of the well as possible during the flushing stage. For fractured or very porous rock formations, it may be necessary to move the pump up and down the length of the exposed borehole to assure water movement into the entire well bore.

Pumping Rate When Flushing
Maximize the pumping rate. The greater the volume and velocity of water being pumped, the more effective the flushing will be.

Duration of Flushing
Generally, the longer the flushing time the better. A suggested minimum is to pump until at least 20 casing volumes have discharged from the well (Schnieders - Personal contact).

> Example: A 100-foot deep 5-inch well has a casing volume of 100 gallons. A minimum of 2,000 gallons of water (20 casing volumes times 100 gallons) should be flushed from the well.

Flushing Without Chlorination
In some cases, flushing without further chlorination has been effective in correcting contamination problems. Some local health departments have found that allowing water to discharge from a garden hose continuously for a period of at least 24 hours or more has corrected the contamination problem without the need to treat with chlorine. The hose is discharged into a roadside ditch or into the yard away from any on-site sewage disposal system. Open the sill cock valve all the way during the flushing stage.

Sampling After Flushing
A water sample should be collected from the water supply after the flushing period to determine if the flushing process has corrected the bacterial contamination problem. If coliform bacteria are not present in the water sample analyzed, the flushing may have successfully disinfected the water supply. However, a second water sample is recommended approximately one week later to verify that the bacterial contamination problem has been corrected.

Discharge Water Management
The initial discharge of water from a recently chlorinated well may contain elevated levels of chlorine and chlorination byproducts. Do not run the water into a surface water body. Avoid flushing for long periods if discharge water will flow onto neighboring property or roadways, or otherwise create a nuisance condition.

Chlorine Sources and Characteristics

Although there are several chemical disinfectants that may be used to treat a well, this manual only addresses the use of chlorine, the water supply disinfectant most commonly used.

Chlorine is a bactericidal chemical that destroys or inactivates coliform bacteria that it comes into contact with. Chlorine attempts to disrupt the normal life processes of an organism. This is done by penetrating the cell wall of the organism and upsetting the natural life cycle processes or altering the organism's enzymes. With the cycle so disrupted, the organism either dies or cannot reproduce and the water is made bacteriologically safe (Connell, 1976).

Treatment with a chlorine solution is an essential component of efforts to eliminate microorganisms that have invaded an existing well or have been introduced into a new well during its construction.

Water Supply System Chlorination Objective
To expose all parts of the water system to a chlorine solution of sufficient strength for an adequate time period. The "water system" includes:

1. Water bearing formation around well screen or a rock borehole.
2. Well casing.
3. Pump.
4. Pressure tank.
5. Piping.

Commonly Used Chlorine Sources
Sodium hypochlorite and calcium hypochlorite are the most common sources of chlorine used for disinfection of onsite water supplies. The following provides information on these two chlorine sources:

Sodium Hypochlorite (common household bleach)

- Clear to slightly yellow colored liquid with a distinct chlorine odor.

- Common laundry bleach - 5.25 to 6.0 percent available chlorine, when bottled. Use unscented only. Scented bleaches may leave an odor for extended periods of time, even after the chlorine has been flushed out of the water supply. Do not use bleach products that contain additives such as surfactants, thickeners, stabilizers, and perfumes. These additives may contain hazardous chemicals and should not be used for treating drinking water. Always check product labels to verify product content and use instructions.

- Swimming pool chlorine - 10.0 to 12.0 percent available chlorine. Note that there are types of chlorine other than sodium hypochlorite available for swimming pool use, and these should not be used for treatment of water supplies unless certified as meeting American National Standards Institute (ANSI)/National Sanitation Foundation, Inc. (NSF) Standard 60. Swimming pool chlorine products may contain UV inhibitors, algaecides, or other additives that should not be added to water supplies. Always check product labels to verify product content.

- Higher concentrations of chlorine in sodium hypochlorite solutions are generally not available. Above 15 percent, the stability of hypochlorite solutions is poor, and decomposition and the concurrent formation of chlorate is of concern (Connell, 1996).

- Limited shelf life – Sodium hypochlorite solutions are of an unstable nature due to high rates of available chlorine loss (Pecora, et al., undated). Over a period of one year or less, the amount of available chlorine in the storage container may be reduced by 50 percent or more.

Solutions more than 60 days old should not be counted upon to contain the full amount of available chlorine originally in solution (Driscoll, 1986)(Campbell, et al., 1973).
The stability of hypochlorite solutions is greatly affected by heat, light, pH, initial chlorine concentration, length of storage, and the presence of heavy metal cations (White, 1999)(Connell, 1996). These solutions will deteriorate at various rates, depending upon the specific factors:

1. The higher the concentration, the more rapidly the deterioration.
2. The higher the temperature, the faster the rate of deterioration.
3. The presence of iron, copper, nickel, or cobalt catalyzes the deterioration of hypochlorite. Iron is the worst offender (White, 1999).

Because light and heat accelerate decomposition of sodium hypochlorite solutions, product degradation is less pronounced when containers are stored in a dry, cool, and darkened area or in a container protected from light (AWWA Manual M20 1973). A test kit should be used to check the final chlorine residual in a prepared chlorine solution to assure that you have the intended concentration.

As a General Rule
One gallon of 5.25 percent bleach in 100 gallons of water will make a solution of 500 parts per million (ppm) (Keech, 1983).

Calcium Hypochlorite

- Dry white powder, granules, or tablets.
- 60 to 70 percent available chlorine.
- 12-month shelf life if kept cool and dry.
- If stored wet, looses chlorine rapidly and is corrosive.

As a General Rule
Three-quarters of a pound (about 1 1/2 cups) of granular calcium hypochlorite mixed in 100 gallons of water will make a 500 ppm solution. A chlorine test kit should be used to check the final chlorine residual in a prepared chlorine solution to assure that you have the concentration intended.

Calcium Hypochlorite Tablets
The use of calcium hypochlorite tablets dropped into the top of a well is not recommended as the sole means of disinfecting a well for the following reasons:

1. Tablets are designed to be slow dissolving. This characteristic is not conducive to getting all the available chlorine into the chlorine solution during the desired chlorination time interval.
2. Conditions in a well are not conducive to dissolving chlorine tablets. The water is cold and there is very little agitation or turbulence in the bottom of a well. Tablets are designed for use in applications where the water is warm and water is flowing past the tablets such as in a basket in the recirculation line of a swimming pool.
3. It is difficult to get uniform distribution of chlorine if the tablets are dumped into a well. There will be a strong concentration of chlorine around the tablets, but not in other portions of the well.
4. Tablets poured into the top of a well may lodge on the interior of the pitless adapter or on top of the submersible pump causing corrosion (Franklin Aid, 1987). Cases of severe corrosion of submersible pumps leading to premature failure due to chlorine tablets have been reported in Michigan.
5. The tablets cause high concentrations of chlorine in the bottom of the well, causing chemical interactions with the ground water leading to excessive scaling.

If tablets are to be used as a source of chlorine for a chlorine solution, they must first be broken up and dissolved in a 5 gallon pail or bulk tank. Otherwise, they may remain in the bottom of the well for extended time periods and provide poor distribution of chlorine.

Which is Best, Sodium Hypochlorite or Calcium Hypochlorite?
Current experiences of water well drilling contractors and ground water specialists suggest sodium hypochlorite is more effective (Mansuy, 1999; Schnieders, June, 2001). However, this may be associated with the quality of the ground water in the well being treated rather than with the source of the chlorine itself.

In Michigan, there is an abundance of calcium based materials in both bedrock wells and those finished in glacial deposits. Calcium hypochlorite already has a high concentration of calcium (the white cloudy appearance). At 180 ppm (or approximately 10 grains) of hardness, water is saturated with calcium to the point that it precipitates out of the solution, changing from the dissolved state to a solid state (Schnieders, December 2001).

Introducing a calcium hypochlorite solution into a calcium rich aquifer can cause the formation of a calcium carbonate (hardness) precipitate that may partially plug off the well intake. The plugging can interfere with the distribution of the chlorine solution and possibly reduce the production capabilities of the well (Coombs, 2001; Mansuy, 2001; Schnieders, June 2001; and Smith, 2001). Sodium hypochlorite does not have the tendency to create the precipitate, which may be why it appears to be a more effective disinfectant.

If the calcium carbonate concentration in the ground water is above 100 ppm (mg/l), the use of sodium hypochlorite is recommended instead of calcium hypochlorite (Schnieders, December 2001).

ANSI/NSF Certification
Sodium hypochlorite or calcium hypochlorite that contain other chemicals or additives, such as stabilizers, perfumes, algaecides, or other chemicals that are used for water supply disinfection should be certified that they are in compliance with or surpass the American National Standards Institute/NSF International (ANSI/NSF) Standard 60 for Drinking Water Treatment Chemicals – Health Effects, or an equivalent standard.

Germicidal Efficiency of Chlorine
The major factors affecting the germicidal efficiency of the free chlorine residual process are: chlorine residual concentration, contact time, pH, and water temperature. Increasing the chlorine residual, the contact time, or the water temperature increases the germicidal efficiency. Increasing the pH above 7.5 drastically decreases the germicidal efficiency of free chlorine (White, 1999). Varma and Baumann (Varma, 1959) performed a comprehensive literature review compiling chlorine residuals and contact times needed to kill vegetative bacteria, viruses, and amoebic cysts. Based on this review, a 99.6 to 100 percent kill can be achieved by maintaining a 50 ppm chlorine residual at an approximate pH of 6.4 to 8.6 for 4 to 6 hours at a temperature of 20 to 29^{o}C (68 to 84^{o}F). These concepts and others are discussed in more detail in the following sections.

Form of Chlorine
The form of chlorine that is in a chlorine stock solution is an important factor in how effective the solution is as a disinfectant. Chlorine dissolved in water, regardless of whether sodium hypochlorite or calcium hypochlorite is used as the source of the chlorine, generally exists in two forms, depending on the pH of the water:

- HOCl - hypochlorous acid (biocidal)
- OCl - hypochlorite ion (oxidative)

Hypochlorous acid is the most effective of all the chlorine residual fractions (White, 1999). Hypochlorous acid is 100 times more effective as a disinfectant than the hypochlorite ion (Schnieders, 1998). It is generally thought that the death of bacterial cells results from hypochlorous acid oxidizing essential bacterial enzymes, thereby disrupting the metabolism of the organism. The germicidal efficiency of hypochlorous acid is due to the relative ease with which it can penetrate cells. This penetration is comparable to that of water, and can be attributed to both its modest size (low molecular weight) and its electrical neutrality (absence of an electrical charge) (White, 1999) (Hackett, 1987).

The hypochlorite ion is not as strong an oxidizing agent as hypochlorous acid and the negative charge and the size of the ion impedes its ability to penetrate an organism's cell wall. Hence, the hypochlorite ion is not as effective a disinfectant agent as hypochlorous acid (Hackett, 1987).

pH Effect on Chlorine

Chlorine is a more effective disinfectant at pH levels between 6.0 and 7.0, because hypochlorous acid (the most effective form of chlorine) is maximized at these pH levels (Schnieders, February 1998). Controlling the pH of a chlorine solution increases the effectiveness of the chlorination process. Any attempt to disinfect water with a pH greater than 9 to10 or more will not be very effective (White, 1999) (Connell, 1996).

The pH determines the biocidal effects of chlorine. By controlling the pH of the solution that the chlorine is in, the form of chlorine (hypochlorous acid or hypochlorite ion) can be controlled. If the amount of hypochlorous acid can be maximized by controlling the pH, the effectiveness of the chlorine is significantly increased. The following chart demonstrates how pH affects the form of chlorine.

Effect of pH on Type of Chlorine*		
	Approximate percentage at 32 to 68 degrees F	
pH	Hypochlorous Acid	Hypochlorite Ion
5	100	0
6	97-98	2-3
7	75-83	17-25
7.6	42-63	47-58
8	23-32	68-77
9	3-5	95-97
10	0	100

* From Schnieders, February 1998

Chlorine will raise the pH when added to water. As noted in the chart above, raising the pH reduces the amount of hypochlorous acid present. By increasing the concentration of chlorine, and subsequently raising the pH, the chlorine solution is actually less efficient as a biocide. At higher pH levels, hypochlorite ion is formed, which is the least effective of the two forms of chlorine.

Controlling the pH of the water in the aquifer is not practical. However buffering or pH-altering agents may be used to control pH in the chlorine solution being placed in the well.

Temperature Effect on Chlorine

As temperatures increase, the metabolism rate of microorganisms increases. With the higher metabolic rate, the chlorine is taken into the microbial cell faster, and its bactericidal effect is significantly increased. Therefore, the higher the temperature the more likely the disinfection will produce the desired results.

Steam injection has been used to elevate temperatures in a well and the area surrounding the wellbore as a means of treating for biofouling organisms, and this process may have some application in controlling ground water temperatures (Alford, et al., 1999). However, it is limited to wells with steel casings, and the expense of the treatment generally renders it impractical for use at residential wells.

Interfering Substances Effect on Chlorine

Dirty surfaces and turbid water cannot be effectively treated with chlorine. There may be substances in the water and on surfaces within the well that bind up or use up available chlorine resulting in less chlorine (free chlorine residual) being available to serve as a disinfectant (LeChevallier, et al., 1981) and thereby decreasing the effectiveness of the chlorination process. This binding or using up of chlorine is called chlorine demand. The interfering substances may include:

1. Inorganic matter (sand, silt, clay).
2. Organic matter (synthetic chemicals or biological material).
3. Drilling mud/additives.
4. Dissolved iron and other minerals in the ground water or in the water being used for preparing the chlorine solution.
5. Drill cuttings.

Reaction with reducing ions such as iron, manganese, nitrite, sulfide, and sulfite form the initial chlorine demand. The chlorine reduced to chlorides in these reactions has no disinfection ability. Additional chlorine will then react with ammonia and certain organic compounds to form chloro-organic compounds and chloramines. Combined residuals reach a peak, then decline as more chlorine is added, offering limited disinfection ability. The point at which combined chlorine residuals reach a minimum and a free chlorine residual begins to appear, is known as the breakpoint. Up to this point chlorine demand (dosage minus residual) varies with dosage. Beyond the breakpoint the free chlorine residual increases directly with dosage (Jones, 1979).

The major chlorine demand of concern in well disinfection is not in the water, but on surfaces of the well. Nuisance organisms (organisms able to reproduce in the environment of the well) often produce large quantities of organic matter. The result is a high chlorine demand and sufficient organic energy for the possible propagation of coliform if the water temperature is above 13° C (55.4° F)(Jones, 1979).

Many nuisance organisms are filamentous or slime formers and produce particles that settle to the bottom of the well, along with soil particles, scale, and other debris. It is wise to assume that 20 percent of the chlorine demand exists at the bottom of the well. In wells that have been inadequately disinfected several times, over 90 percent of the chlorine demand may be at the bottom due to settle slimes and other debris loosened in previous disinfection attempts (Jones, 1979).

Only clean surfaces in a well render themselves to effective disinfection with chlorine (Coombs, 2001). Proper development of a newly constructed water supply, proper preparation of an existing water supply, and thorough flushing of a water supply can effectively clean exposed surfaces, remove turbid water, and helps remove most interfering substances.

Chlorine Concentration

Exposure of an unprotected coliform organism to even very low concentrations of chlorine will kill the microorganism. However, the microorganisms may be protected from exposure to the chlorine by protective slimes, cuttings, drilling fluid, scale, etc. These interfering substances, as discussed earlier, will use up available chlorine, thereby allowing the microbes to survive because of insufficient chlorine concentration.

The initial chlorine concentration in the chlorine solution needs to be high enough to assure that there is sufficient chlorine to make up for this “chlorine demand,” and still have a residual of chlorine left to kill the vulnerable microorganisms.

In practice, chlorine concentrations should be kept between 50 and 500 parts per million (ppm) and the standard recommended concentration is 200 ppm (Schnieders, 2001). This allows for enough chlorine to satisfy chlorine demand (interfering substances), and still provide sufficient free available chlorine to disinfect (50 ppm). Exceeding these levels may cause damage to the well or actually reduce the effectiveness of the chlorination process as follows:

1. At higher concentrations of chlorine (in excess of 500 PPM), the corrosivity of the stock solution is significantly increased, creating a potential for damage to metal well components (submersible pumps, check valves, etc.)(Franklin Aid, 1987) **The use of chlorine solutions with chlorine concentrations in excess of 500 ppm is not recommended.**
2. In the presence of higher concentrations of chlorine, the surface of biofilms and mineral scale may be oxidized to form a hard, tight surface (Schnieders, 2001). This sealing of the surface layers then reduces the chance that chlorine will penetrate into the material to make contact with the microorganisms that may exist there.

Contact time

Contact time is the length of time that the chlorine solution is left in the water supply. Sufficient time is needed to allow the residual chlorine to penetrate into biofilms or other materials that may be present, in order to reach any microorganisms that may be present.

During the contact time the chlorine residual should be maintained in the water supply system for 4 to 12 hours (Coombs, 2001). For increased contact time to be most effective, the pH of the chlorine solution in the well must be maintained between 6 and 7 to keep the chlorine in a nonoxidative state (hypochlorous acid). If pH control is not going to be used during periods of increased contact time, use concentrations of chlorine 50 ppm or less (Schnieders, 2001).

The longer the contact time, the more likely the chlorination procedure will be successful, especially if proper concentrations of chlorine are used at controlled pH conditions. Caution should be exercised during periods of extended contact times to minimize corrosive damage to pumps and other well components by controlling levels of pH and using lower concentrations of chlorine.

Simple Chlorination

Simple chlorination is the process of adding a small volume of chlorine solution into the top of the water well, followed by circulating the chlorine into the water supply's distribution system. This simplified procedure is used to disinfect the upper portion of a well casing, the well pump, the drop pipe, the water service line, the pressure tank, and the building distribution system. As the pump is operated, the chlorine is drawn to the pump intake and from there into the distribution system. Simple chlorination can be effective for existing water supplies and should not be used for newly constructed wells unless sampling shows the well is not the source of the bacterial contamination.

With simple disinfection, there is no assurance that the chlorine will get to the bottom of the well or into the aquifer around the well. Water is flowing from the bottom of the well up to the pump intake, minimizing the chance that any portion of the well below the pump intake will be exposed to the chlorine. When used for treating existing water supply systems, it should be used only for the first treatment. If simple chlorination is unsuccessful at disinfecting the existing well, the bulk displacement method of well chlorination (See next section of this manual) should be used.

Disinfection of flowing wells, wells with deep well jet pumps, wells with drawdown seals, or wells in pits should not be attempted by well owners. A registered water well drilling contractor should be contacted to perform well treatment on these types of wells.

Simple Chlorination Procedures
The following simple chlorination procedures are recommended for treating a typical 4- to 6-inch diameter home water well system with a submersible pump.

1. **Remove Turbidity** - If the well water is not clear, pump it to waste until it clears up before starting the chlorine treatment. Turbidity (cloudiness) in the water can reduce the effectiveness of the chlorine.
2. **Bypass Cartridge Filters** - If the water system has a cartridge filter, place its valve in the "bypass" position and remove the cartridge housing and cartridge. Discard the old cartridge. Rinse the housing with a solution of 1 tablespoon of bleach and a cup of water. Drain the housing and insert a new filter cartridge. Reinstall the cartridge housing and filter, but leave the cartridge filter valve in the bypass position until the chlorine has been completely flushed from the water supply after treatment.
3. **Bypass Other Water Treatment Units** - Bypass water treatment units, such as water softeners, reverse osmosis (RO) systems, and iron removal systems. Follow manufacturer's recommendations pertaining to disinfection of treatment units. Then leave the units in by-pass position until all chlorine has been flushed. High concentrations of chlorine can damage softener resin (Keller, 1991) and RO membranes.
4. **Check Water Well Record** - Check the water well record to see if there are drawdown seals or other devices that will prevent chlorine from reaching the water. If there are, or if you are unsure, contact a Michigan registered water well drilling contractor to perform the disinfection.
5. **Turn Off Power to the Pump Before Removing the Well Cap.**
6. **Prepare a Chlorine Solution.** Prepare a chlorine solution using the table below. Any brand of unscented liquid household bleach that contains 5¼ to 6 percent available sodium hypochlorite may be used. **Swimming pool chlorine and scented products should be avoided.**

Chlorine Solution Table	
Well Diameter	**Amount of bleach per 25 feet of well depth**
4 inch	1 cup
5 inch	1½ cups
6 inch	2 cups

Example: A 4-inch diameter well 150 feet deep would need 6 cups of bleach to treat the well.

7. **Mix.** Mix the bleach (from above chart) with 5 gallons of clean water in a clean plastic or glass container and add an additional 2 cups of bleach (to assure sufficient chlorine for disinfection of the pressure tank, water heater, and distribution system).

   Example: From the chart above, a 4-inch diameter well 150 feet deep would need 6 cups of bleach to treat the well. Therefore, a total of 8 cups of bleach will be mixed with the 5 gallons of water.
8. **Pour.** Slowly pour the mixture into the top of the well.
9. **Circulate.** After the chlorine has been applied to the well, turn the pump on and circulate the chlorinated water through the service lines and plumbing. Attach a hose to an outside tap and run the water to waste (discharge onto the ground surface) until a chlorine smell can be detected in the water and the water is clear. Do not discharge the water into a sewage disposal system.

10. **Recirculate. Do not start this process until the water from the hose is clear.** Use the garden hose to recirculate the chlorinated water back into the top of the well. Wash down the inside of the casing for at least 30 minutes. During this process, water circulates from the pump, through the drop pipe, service line, pressure tank, distribution piping, and hose back into the top of the well. This recirculation of the chlorinated water will help assure a uniform distribution of chlorine between the top of the water column in the well and the pump intake (Jones, 1979). The recirculation of chlorinated water enhances the chlorination process by not only exposing surfaces to chlorinated water, but also to the cleaning effect of agitated (flowing) water.
11. **Reinstall the Well Cap.** After the recirculation period, turn off the water to the hose and cap the well.
12. **Open Taps.** Open each tap within the home, one at a time, starting closest to the pressure tank, and run water until a strong chlorine smell is present. Close the tap. Do not forget to flush each hot water tap. See the “Distribution System Disinfection” section of this manual for a more detailed description of procedures to be used to disinfect a distribution system.
13. **Contact Period**. Allow the chlorine to remain in the water supply for 4 to 12 hours, preferably overnight (Lehr, et al., 1988). Contact time is an important part of the chlorine treatment process. The longer the chlorine is allowed to remain in the water supply system, the better the chance that the chlorine will contact and kill microorganisms that may be present. Water use during the contact time should be minimized to assure that a chlorine residual remains in the well.
14. **Flush.** After the contact period, pump to waste to remove the chlorine from the water supply. Flush until the chlorine smell can no longer be detected. After the chlorine smell can no longer be detected, it is recommended that flushing be continued for an additional 1 to 2 hours, since there may still be traces of chlorine in the well. This will help assure that all traces of chlorine have been removed. Flushing for an extended period of time after treatment with chlorine will also help clean the system because of the scouring action of the water.

    For this period of pumping to waste, use a hose connected to an outside tap, discharging into the yard, a roadside ditch, etc. If possible, avoid pumping chlorinated water on lawns and landscape plants. The outside tap should be allowed to run in the fully open position to maximize the pumping rate.

    - Do not run the water into the household plumbing, and subsequently into the septic tank/tile field, during this pumping period. Overload of the drainfield can occur.
    - Do not run the water into a lake, stream, or other body of water.

15. **Reactivate Treatment Systems.** When all traces of chlorine are gone, place the disinfected water treatment units back online.

16. **Sample.** Collect a bacteriological water sample. Before sampling, a check for residual chlorine should be done using a chlorine (swimming pool) test kit or a chlorine meter. The use of chlorine test strips is not practical since most strips do not measure concentrations less than 1.0 ppm. If a test kit or chlorine meter is not available, continue to flush for at least 2 hours after there is no chlorine smell, before collecting the water sample.

Turbidity as a Result of the Chlorination Process

Water from a water supply system that has been treated with chlorine can be turbid due to the effect of the chlorine on minerals in the water (such as iron) and biofilms that may be present. Extended pumping normally clears the water of turbidity.

Bulk Displacement Chlorination

Bulk displacement is the recommended method of introducing a prepared chlorine solution into a well. It involves preparing a predetermined volume of disinfectant solution and pouring or pumping the solution into the well. The chlorine solution displaces water in the casing, screen/borehole, and aquifer, replacing it with the chlorinated solution. This is the most practical method to assure that chlorine is uniformly distributed throughout the well and reaches the aquifer surrounding the well intake.

CHLORINE SOLUTION PREPARATION

1. **Determine the volume of the chlorine solution that needs to be prepared.**
   The volume of the chlorine solution should be a minimum of 5 times the combined volume of the casing and screen/borehole. This volume helps ensure that there is enough disinfectant to fill the casing/borehole and flow out into the aquifer around the screen or rock borehole.

   Example - a 125-foot deep well with 5-inch diameter casing, with a static water level of 25 feet below ground, has a volume of 100 gallons. Therefore, the volume of the stock solution should be 500 gallons.

   For fractured limestone and other highly porous formations, the volume of the chlorine solution should be increased to assure chlorine contact with all contaminants that may have been introduced into the formation.

   For use in determining casing and screen/borehole volumes, use the following:

   2-inch well = .16 gallons per foot
   4-inch well = .65 gallons per foot
   5-inch well = 1.0 gallons per foot
   6-inch well = 1.5 gallons per foot

2. **Adjust the pH of the water in the bulk tank to 4.5 before adding chlorine (Optional, but recommended)**
   Controlling the pH of a chlorine solution is recommended (Coombs, 2001; Mansuy, 2001; Schnieders, June 2001; Smith, 2001), especially when previous disinfection attempts have been unsuccessful. See the discussion of pH control in the "Factors Affecting Effectiveness of Chlorination" section of this manual.

White distilled vinegar and chlorine bleach

Adding vinegar to bulk tank

   Use a well cleaning acid (carefully following manufacturers' instructions) to lower the pH of the chlorine solution being prepared in the bulk tank to 4 to 4.5. After the acid is added to the water in the bulk tank, the water must be agitated to assure uniform distribution of the acid. An air line, a recirculating pump, paddles, or other agitation methods should be used.

Agitation of a bulk tank using a paddle

Use pH test strips to check the pH level. Make sure the pH has stabilized by testing several times.

Caution! At a pH of 5 or below, some chlorine gas is formed. More gas evolves if the pH drops below 4. Fortunately the chemical reaction forming the chlorine gas is slow at or near a pH of 4 and the hypochlorite solution quickly begins to neutralize the acid as soon as it is added, raising the pH to a safer level. Above a pH of 5, no chlorine gas is produced (Schnieders, February, 1998). Add the acid to the source water only in a well ventilated area, and avoid exposure to the fumes from the acid container.

Do not use source water that has hydrogen sulfide (H_2S) present unless the water has been aerated enough for the H_2S to dissipate. Adding an acid to water containing H_2S will cause the H_2S gas to be immediately released from the water. Exposure to elevated levels of H_2S is a serious health risk.

Use Only NSF Certified Acids
There are several commercial well cleaning products on the market that have been developed to lower the pH of the source water. Many of these products now meet ANSI/NSF Standard Number 60. Contact a water well supply house or manufacturer's website for information concerning these products.

Recommended Acids

Acetic Acid:
This is a good biocide and biofilm dispersing acid. Acetic acid is usually sold as glacial acetic acid, which is at least 95 percent (except for vinegar). In this form, it is extremely dangerous and very corrosive to skin and lungs (Mansuy, 2001; Schnieders, June 2001; Smith, 2001).

Vinegar is a weak form of acetic acid, and can successfully lower the pH of source water (Schnieders, 2001). There are several types of vinegar available in a grocery store, but the **white distilled vinegar** is the recommended type. Vinegar is:

- Safe to use.
- Readily available in most grocery stores.
- Inexpensive.

As a General Rule When Using Vinegar - Sources of water to be used for the chlorine solution may differ in quality and adding the same amount of a specific acid may produce slightly different results from case to case. A general rule is to add 1 gallon of vinegar to each 100 gallons of water to lower the pH to the desired starting point of 4 to 4.5 pH (remember to always check with suitable pH test strips for that range).

Sulfamic Acid:
Relatively effective against carbonate scales, but is not effective against biofouling.

Relatively safe to handle.

May form insoluble solids in a water well (Smith, 2001). It produces the sulfamate ion which is very soluble for up to 6 to 12 hours. After that, it hydrolyzes to sulfate and then produces the insolubles

Hydroxyacetic Acid:
Good biocidal properties.

Acids Not Recommended

Oxalic Acid:
Fairly dangerous to skin and eyes and produces oxalates, which are poisonous.

Citric Acid:
Food source for bacteria and is difficult to get out of a well.

Muriatic (Hydrochloric) Acid:
Low concentration (20 percent) of hydrochloric acid

Hazardous to handle. Contractors should avoid using muriatic acid due to its hazardous properties. Several deaths and injuries have occurred in Michigan that were associated with use of muriatic acid for water well rehabilitation (Keech, November 1983)(Michigan Department of State Police, 2001)(Oceana County Sheriff's Department, 2001).

Avoid the use of muriatic acid

Relatively ineffective against biofouling.

Phosphoric Acid:
One of the milder mineral acids - Leaves phosphate residue behind which can stimulate bacterial growth and magnify biofouling problems. Use of this acid must be followed by aggressive agitation of the aquifer to remove any of the phosphate residue that may have been deposited.

3. **Add chlorine to the source water**
Add chlorine to the source water and agitate to assure proper chlorine distribution. An air line, a recirculating pump, paddles, or other means of agitation should be used.

Add enough chlorine to obtain a concentration of approximately 200 ppm chlorine (Schnieders, 2001).

Add chlorine to the bulk tank to lower the pH

Use a paddle to agitate

If calcium hypochlorite is used as the source of chlorine, it should be dissolved in a pail of water before being added to the prepared source water. After being added to the bulk tank and thoroughly mixed, the calcium carbonate impurities should be allowed to settle to the bottom of the tank. The clear solution above the sediment is then drawn off for discharge into the water well. Use sodium hypochlorite if the well water has more than 100 ppm dissolved calcium (calcium carbonate).

The addition of chlorine to the source water should take place in a well ventilated area. Hypochlorite fumes or chlorine gas can become concentrated in a confined area and may cause severe respiratory problems.

4. **Verify final pH and chlorine concentration**
For maximum bactericidal efficiency, the final pH of the chlorine solution should be between 6 and 7.

pH test kit

pH test strips

Use a chlorine test kit or meter to verify proper levels of chlorine and a pH test kit to verify proper levels of pH. Adjust as necessary. Note that the use of pH test strips may not be practical after the chlorine has been added to the stock solution because of the bleaching effect of the chlorine on the strips.

CHLORINE SOLUTION APPLICATION

Use the following procedures to apply the chlorine solution to the well:

1. **Pump to waste** - Turbidity in the water can reduce the effectiveness of the chlorine. If the well water is not clear, pump it to waste until it clears up before starting the chlorine treatment.

2. **Bypass treatment units** - Bypass water treatment units, such as cartridge filters, water softeners, reverse osmosis (RO) systems, and iron removal systems. Following manufacturer's recommendations, disinfect the treatment units with chlorine. Then, leave the units in by-pass until the chlorine has been completely flushed (high concentrations of chlorine can damage softener resin and RO membranes, so pay attention to manufacturers' instructions).

3. **Application of chlorine solution into the well using bulk displacement** - After the chlorine solution has been prepared (see previous section), apply the chlorine solution into the well. Delivering the chlorine solution with sufficient hydraulic energy to effectively penetrate all areas of the well is crucial (Mansuy, 2001).

Discharging a chlorine solution into a screened well

Assure that the wellhead area is well ventilated, especially if the well is in a confined space such as a well house, well pit, or basement offset. Use appropriate safety precautions and follow state laws when working in confined spaces.

For screened wells - the chlorine solution may be discharged directly into the top of the well. The solution will displace the water in the casing and screen, and force the chlorine solution out into the formation.

For screened wells in extremely coarse formations or where screen lengths over 10 feet are used - a jetting tool extending into the screen to apply the chlorine solution is recommended. The jetting tool will force the solution further out into the formation, and the jetting action will help break loose cuttings and drilling fluids that have been trapped in the geologic materials outside the well.



Examples of typical jetting tools

For rock wells – Pump the chlorine solution through a tremie pipe extending to the bottom of the borehole and slowly withdraw the tremie pipe as the solution is added. This helps uniformly distribute the chlorine solution throughout the uncased portion of the borehole. A jetting tool or other means of agitation is recommended during or after application of the chlorine.

4. **Agitation** - Agitation of the well is recommended when disinfecting existing wells where biofilms are likely, or where repeated chlorinations have not been successful. Agitation of the chlorine in the well will help distribute the chlorine into the aquifer, and will enhance the penetration of the chlorine into slimes, scale, or other bacteria containing material. The recommended method of agitation is by surge block or jetting tools.

5. **Circulation** - After the chlorine has been applied to the well, turn the pump on and circulate the chlorinated water through the service lines and plumbing. Use a garden hose attached to an outside tap to run the water to waste (discharge onto the ground surface) until a chlorine smell can be detected in the water and the water is clear.

6. **Recirculation** - Use the garden hose to recirculate the chlorinated water back into the top of the well and wash down the inside of the casing for at least 30 minutes (the longer the better) with the chlorinated water. Do not start the recirculation until water from the hose is clear. Do not discharge turbid water from the hose back into the well. During this recirculation process, water circulates from the pump, through the drop pipe, service line, pressure tank, distribution piping, and hose back into the top of the well. Recirculation enhances the chlorination process by exposing these surfaces to chlorinated water and cleaning water contact surfaces within the well.


Recirculation of chlorinated water

Some water well drilling contractors have extended the recirculation time to several hours. Extended recirculation has been shown to increase the effectiveness of the disinfection process. During extended recirculation a seal needs to be placed on the wellhead to keep contaminants from entering the well.

Where practical, the pump intake should be located as close to the bottom of the well as possible during this period of recirculation. After completing the recirculation, install the permanent well cap.


Protected wellhead during recirculation

7. **Open taps** - Open each tap within the home, one at a time, starting closest to the pressure tank, and run water until a strong chlorine smell is present. Check with a chlorine test strip, then close the tap. Do not forget to flush each hot water tap. See the “Distribution System Disinfection” section of this manual for a more detailed description of procedures to be used to disinfect a distribution system.

8. **Contact time.** Allow the chlorine to remain in the water supply for 4 to 12 hours, or overnight (Lehr, et al., 1988). Contact time is an important part of the chlorine treatment process. The longer the chlorine remains in the water supply system, the better the chance that the chlorine will contact and kill microorganisms that may be present. Water use during the contact time should be minimized to assure that residual chlorine remains in the well. The well drilling contractor should notify building occupants that the water is being disinfected and warned not to consume or bathe in the water until the disinfection is complete.

9. **Flush.** After the contact period, pump to waste to remove the chlorine. Flushing should be continued for at least one hour after a chlorine smell can no longer be detected. This helps assure that all traces of chlorine have been removed from the system. Flushing the well for an extended period of time after treatment with chlorine will also help clean the system because of the scouring action of the water.

   While pumping to waste, use a hose to discharge into the yard, roadside ditch, or to another point where a nuisance will not be created. Avoid pumping strong chlorine solutions onto lawns or landscape plants.
   - Do not run the water into the household plumbing, and subsequently into the septic tank/tile field, during this pumping period. This may overload the drainfield.
   - Do not run the water into a lake, stream or other body of water.

10. **Reactivate treatment systems.** When all traces of chlorine are gone, place the already disinfected water treatment units back "on-line.”

11. **Sample.** Before collecting a water sample for bacteriological analysis, check for residual chlorine using a chlorine (swimming pool) test kit or a chlorine meter. If chlorine is still present, continue to flush. If a test kit or meter is not available, continue to flush for at least 2 hours after there is no chlorine smell, before collecting the bacteriological water sample. (See the “Water Sampling for Coliform Bacteria” section of this manual for further details).

Turbidity as a result of the chlorination process
Water in a water supply system that has been treated with chlorine can be turbid due to the effect of the chlorine on contaminants in the water (such as iron and biofouling). Extended continuous pumping normally clears the water of turbidity, unless the turbidity is the result of a well construction defect.

General
For purposes of this document, the distribution system includes the pressure tank, the water heater, water treatment equipment, piping system, and fixtures.

There are two important steps in the disinfection process for existing distribution systems:

1. Flushing
2. Treatment with chlorine

Both are essential to assure that contaminants that have been introduced into the distribution system are effectively removed.

Flushing
Flushing of the distribution system helps remove loose materials that may be in the system. These materials can interfere with the chlorination process by using up available chlorine and preventing the chlorine from coming in contact with the bacteria that may be lodged in the materials. The materials may include:

1. Debris that has accumulated in the pipes, including loose bits of solder, metal shavings, dirt, or loose scale.
2. Greases.
3. Flux residuals from the soldering of copper pipes.
4. Solvents and glues from the solvent welds used with plastic pipes.
5. Insects that may have entered the distribution system during construction.
6. Sand or other material from the well that may have been pumped into the distribution system.

As with the water well application, water moving through the distribution system can effectively help remove bacteria by the scouring and diluting action of the water.

The distribution system flushing process should not take place until the water from the well is free of sand, silt, or other turbidity. If a problem of this nature exists, it must be corrected before flushing of the distribution system.

Flushing must take place before chlorine treatment of the well or distribution system.

The flushing of the distribution system should take place in the following order:

1. Pressure tank. If the pressure tank has debris in it, it may be discharging debris into the distribution system. It would be counter productive to flush the pipes first, only to have debris reintroduced into them from the tank.
2. Hot water tank.
3. Water treatment systems.
4. Distribution system piping and fixtures.

Pressure Tank Flushing
Conventional galvanized tanks: These tanks normally have an inlet and outlet above the bottom of the tank. This design leaves a basin at the bottom where scale and other sediment accumulate.

The older style tanks found in residential installations have no access openings into the tank which would allow for cleaning of the tank, so the only way to attempt cleaning of these is by flushing, which is, at best, marginal. The tank can be filled and drained repeatedly until discharge water is no longer turbid, but this will in no way assure removal of contaminants that may be in the debris that remains in the bottom of the tank.

Removal of an old galvanized tank and replacing it with a bladder/diaphragm type tank is the most practical, efficient way of attempting to correct a coliform bacteria problem that may be related to the tank.

Bladder/diaphragm tanks: These tanks normally have only one pipe entering the tank. This opening serves as both the inlet and outlet for the tank and is located at the bottom center of the tank. These tanks are flushed out during each pump cycle, since the tank is nearly emptied of all water when the pump comes on. Most of the sediment or scale that may have entered the tank with the water is flushed out as the water is discharged from the tank.

Water Heater Flushing and Treatment with Chlorine

Hot water tanks have a basin at the bottom of the water heater tank that allows for the collection of scale and other debris that may have been introduced into the tank from the well or mineral in the water. Biofilms may also be present in the tanks. These biofilms and debris must be removed to effectively disinfect a water heater tank. However, thorough cleaning of most domestic water heaters is not possible, since there are no access openings into the tank. The only way to attempt cleaning is by flushing, using the boiler drain (faucet) near the bottom of the tank. Flushing may remove much of the debris in the tank, but complete removal of all material cannot be assured. The flushing of the water heater must take place prior to the addition of chlorine into the water supply system.

Suggested water heater flushing procedures:

1. If electric, turn off power to the water heater element or if gas, set the control to the lowest temperature or off position.
2. Turn off the valve on the water inlet pipe delivering water to the hot water tank.
3. Open the faucet at the base of the water heater, and allow water on the water heater tank to drain. It may be necessary to open a hot water tap at one of the distribution system fixtures to relieve the vacuum that is created as water drains from the tank.
4. After the tank is empty, close the faucet.
5. Open the water inlet pipe valve to refill the tank.
6. Repeat steps 2 through 5 until the water being discharged from the boiler drain is free of any debris or turbidity.
7. Open the water inlet pipe valve, and turn the water heater control back to the operating position.

After the water heater tank has been cleaned to the extent possible by following the above flushing process, treat the tank with chlorinated water. This chlorinated water normally comes from the well, where the chlorine has been introduced into the system.

As a supplement to treatment with chlorine, the hot water tank, as well as the hot water piping system, may be disinfected by turning the heat control on the hot water heater to “High”. This will normally generate hot water temperatures at or above 140^{o} F, temperatures which will kill most bacteria. This hot water can be circulated through the hot water distribution piping to enhance the disinfection of that portion of the water supply. **Extreme caution must be used** to avoid scalding injuries by restricting use of the water supply when the hot water temperature has been increased.

Water Treatment Equipment Flushing and Chlorine Treatment

Household water treatment systems commonly encountered in a home include water softeners, reverse osmosis systems, iron removal systems, hydrogen sulfide treatment systems, and cartridge filters. Organic and inorganic (calcium, magnesium, iron, etc) nutrients which are present in many water supplies will concentrate in these treatment systems. The presence of these nutrients along with the large surface area provided in resin beds and on filter cartridges (Geldreich, et al., 1985) facilitate bacterial growth, and are often the source of bacterial contamination of water supplies (Keller, 1991).

Following are some general water treatment unit cleaning and disinfection procedures to consider:

1. Follow water treatment systems manufacturers' recommended cleaning and disinfection procedures.

2. Water softener resin bed disinfection procedures (Keller, 1991), in the absence of the unit manufacture's recommendations for disinfection:
   a. Fully regenerate the resin bed to the sodium form before starting the disinfection process. This will help prevent metals from precipitating in the bed, causing fouling. Most units have a control setting for this manual regeneration.
   b. Place 4 ounces of standard house hold bleach into the brine well of the salt tank for every one cubic foot of resin in the treatment unit.
   c. Again put the unit into the regeneration mode. This regeneration pulls the bleach from step b above into the resin bed.
   d. It is advantageous to interrupt this second regeneration process and let the bleach sit in the tank for an hour. This will allow greater contact time for more complete disinfection. Make sure there is a residual chlorine level in the effluent before shutting down the regeneration.
   e. After the completion of the second regeneration, to put the unit through a third regeneration. This will help remove any debris that may have broken loose during the disinfection process.

3. The brine (salt) tank associated with a water softener should be periodically cleaned. Water softener salt may contain sand and other impurities that accumulate as sludge in the bottom of the tank as the salt dissolves. The sludge that builds up should be removed periodically to prevent this from becoming a place to harbor bacteria that may then contaminate the distribution system piping when the water softener regenerates.

4. Canister type cartridge filters should be periodically cleaned by putting the filter unit in the bypass position, and removing the canister housing and filter. Clean and rinse the canister housing with chlorinated water, and install a new cartridge filter (properly dispose of the old one). Do not rinse the new cartridge filter with chlorinated water.

Piping and Fixture Flushing

1. Put water treatment equipment (such as water softeners or filters) in the bypass position.
2. Remove and clean faucet aerators or similar devices on the outlets.
3. Each outlet (hot and cold) in the distribution system needs to be individually flushed, one at a time. Outlets include, but are not limited to, sinks, outside taps, bathtubs, shower heads, toilets, laundry sinks, dishwashers, refrigerator ice makers, and clothes washing machines.
4. Start with the outlet closest to the source of water (pressure tank).
5. Turn on the outlet to full volume and flush it until the water being discharged is free of any debris or turbidity.
6. If the outlet is a mixing type fixture (hot and cold water using the same outlet), flush each side separately.
7. Turn off that outlet and proceed to the next closest outlet. Repeat the flushing process.
8. Continue this process, one outlet at a time, until all outlets have been initially flushed.
9. By flushing the outlets one at a time, the flow volume and velocity are maximized to get the most effective flushing possible.
10. The longer the system is flushed the better.
11. Reinstall the cleaned aerators or similar devices that were removed from the outlets prior to the flushing procedure.

Chlorine Treatment of the Distribution System
The objective of the treatment process is to assure that chlorinated water is flushed through every part of the distribution system including all pipes, fixtures, outlets and water heaters.

After the entire distribution system has been flushed as described above, it is ready for treatment with chlorine. Once the chlorine has been introduced into the well and pressure tank the chlorine can be run into the distribution system. See the "Chlorinating a Water Supply Using Simple Chlorination" section of this manual for well chlorination information.

This chlorinated water should be tested to assure that at least 50 ppm chlorine concentration is present. Test at several points in the distribution system.

Introduce the chlorinated water from the well into the distribution system, as follows:

1. Assure that all water treatment equipment is in the "by-pass" position.
2. Starting with the outlet closest to the pressure tank, turn it on until the strong smell of chlorine can be detected. Check with test strips. Outlets include, but are not limited to, sinks, outside taps, bathtubs, shower heads, toilets, laundry sinks, dishwashers, refrigerator ice makers and clothes washing machines.
3. Turn the outlet off and proceed to the next closest outlet.
4. Continue this process until all fixtures and pipes have been filled with the chlorinated water.
5. Both hot and cold water piping and fixtures must be turned on (separately) until the chlorine smell can be detected.
6. It may take an extended flushing period until the chlorine smell can be detected in the first hot water outlet flushed. This is because it will take some time for the water heater to fill with the chlorinated water from the well.
7. After all outlets have been flushed and chlorinated water is in the entire distribution system, the chlorine should remain in the system at least overnight, and as long as possible.
8. The chlorine may be flushed from the system the next day. The chlorinated water should not be discharged into a septic tank/tile field system. It is suggested that a hose be attached to an outside tap, and the chlorinated water discharged to a road side ditch, a sprinkler head, into the yard, etc. Do not discharge to a lake, stream, or other body of water.
9. Continue to run the water until all traces of chlorine are gone from the system. Use a chlorine test kit to verify.
10. Allow the water to run an additional 1 to 2 hours to assure that all traces of chlorine have been removed from the system.
11. Put water treatment equipment back on line. The water treatment equipment must have been flushed and disinfected as described earlier.
12. Collect and submit a water sample for coliform bacteria analysis.

Difficult Cases
If chlorination and flushing of a distribution system is not successful in removing coliform contamination, consider flushing the system with a 10 percent vinegar solution (prepared from white, distilled vinegar) in order to remove any biofilm accumulated. There are also biodispersants on the market that are very effective at biofilm removal. In most cases, however, pH controlled chlorination is more effective than biodispersants in disinfecting distribution systems, especially where high heterotrophic plate counts are found.

Restricted Water Use During Chlorination

The following information should be provided to building occupants after chlorine has been introduced into the water system:

1. ***Do not drink the water and avoid all body contact***.
2. Water use should be minimized to assure that chlorine remains in the well during the minimum contact period.
3. If strong chlorine odors are detected, ventilate the effected area immediately, and minimize exposure to the fumes.
4. Avoid doing laundry, filling fish tanks, watering plants and using water for other purposes where the chlorine may have an adverse effect.

The following page contains a suggested form entitled “Well Disinfecting & Sampling Notice” for use in advising homeowners of chlorination procedures and precautions.

Well Disinfection and Sampling Notice

YOUR WELL WAS DISINFECTED on ____________ at ______ A.M./P.M with a chlorine bleach solution.

Well disinfection is a standard practice required by the Michigan Water Well Construction Code when a new well is completed or an existing well is serviced. The chlorine disinfectant is a safety measure to kill any bacteria introduced during well construction or repair.

DO NOT USE THE WATER FOR DRINKING, COOKING, OR BATHING UNTIL THE DISINFECTANT HAS BEEN COMPLETELY FLUSHED OUT AND A SAFE COLIFORM BACTERIOLOGICAL WATER TEST HAS BEEN OBTAINED. HIGH CHLORINE CONCENTRATIONS SHOULD NOT BE CONSUMED AND CAN CAUSE SKIN IRRITATION.

We ask that you avoid using large quantities of water (such as laundry or lawn watering) <u>for at least the next **10** hours</u> to ensure that the chlorination is effective and to avoid possible household problems:

☐ We were unable to access your house to disinfect your plumbing system.

☐ Please disinfect the plumbing by running water at each plumbing fixture until you can smell chlorine.

After **10** hours the chlorine should be pumped from the well. <u>Do not discharge the water to a surface water body (a lake or stream) or to your septic tank or sewer system</u>.

State regulations require that before placing a new, repaired, or reconditioned water well into service, and after all traces of chlorine are pumped from the well, a water sample shall be collected and found to be free of coliform bacteria (common in intestines of warm-blooded animals).

Well owners are responsible for collecting the sample or arranging for sample collection.

☐ Please contact your local health department to have your water tested.

☐ We will collect a bacteriological water sample at your request. Please call our office to arrange a time.

☐ We have left a water sample bottle for you to collect a water sample for coliform analysis. Please collect a sample 48 hours after all traces of chlorine have been pumped from the system, using the instructions provided. Submit the sample to the laboratory. You will receive a copy of the test results.e

STAMP OR ATTACH BUSINESS CARD

WATER SAMPLING FOR COLIFORM BACTERIA

General
Collecting a water sample for laboratory analysis is the most practical way of determining the suitability of a water supply for drinking purposes. Water sampling is particularly important for a newly constructed or repaired water supply, because of the likelihood that contaminants may have been introduced during construction or repair.

Who Should Sample
For newly constructed wells, the well owner needs to assure that a water sample is collected for bacteriological quality before well use. However, it’s recommended that water samples be collected by a well drilling contractor, public health official, laboratory personnel or other individual familiar with proper sampling techniques.

An individual should consult their local health department to get information on sampling protocol, where to get sampling containers and available laboratories.

Types of Sampling
1. Bacteriological sampling uses coliform bacteria as an indicator organism. Two excellent sources of information about coliform bacteria and their use in drinking water analysis are found in the list of references (Cullimore, 2000 and Edberg, S.C et. al., 2000):
2. General chemical sampling gives an overview of the aesthetic quality of the water and suitability as a drinking water source. The elements or compounds typically analyzed include including hardness, iron, chloride, sodium, fluoride, sulfate, nitrate, and nitrite.
3. Specialized chemical sampling is available to detect heavy metals, volatile organic hydrocarbons, pesticides and other contaminants. These samples are collected to identify a suspected site of contamination or to diagnose a water quality problem.

The bacteriological and general chemistry sampling are the most common types of sampling for both new well construction and monitoring of existing wells. Sampling for other water quality parameters is performed on a case by case basis at the discretion of the local health department or request of the well owner.

Only sampling for coliform bacteria will be addressed in this manual.

Sampling for Coliform Bacteria Analysis - Sampling Locations
Water samples for bacteriological analysis are most often collected from one of three locations:

The sampling tap at the pressure tank. The sampling tap at the pressure tank is used to determine water quality from the source of the water. A water sample from this tap tests the sanitary integrity of the aquifer, well, pump, pressure tank and piping between the well and the pressure tank. Generally, there is no influence from water treatment units or distribution system piping when the pressure tank sampling tap is used.

Typical sampling tap

Kitchen sink. A water sample from the kitchen sink checks the bacteriological quality of the entire water supply system, including the aquifer, well, pump, pressure tank, piping, and any water treatment equipment. This sink is most often used because it is the tap that gets the most use in a household. Most of the water used for drinking and food preparation comes from this tap.

If the kitchen sink tests positive for coliform bacteria, follow-up samples should be collected from both the kitchen sink and from the sampling tap at the pressure tank. This will help identify the source of the coliform bacteria.

The kitchen sink is most often used for sampling

Outside faucets are sometimes used as sampling locations

Outside faucet. A faucet on the outside of the house is sometimes used for collecting a water sample for coliform analysis because inside of the house is inaccessible during the sampling visit, or no other untreated sample tap is available.

Outdoor faucets are not the best sampling location. They are exposed to contamination by insects, rain, snow, and dust. They do not get routine, frequent use and most are threaded.

By using proper sample tap preparation, an outdoor faucet can be an adequate sampling location. First, clean the threads with a disinfectant such as an alcohol wipe or a clean cloth soaked in a chlorine solution. A spray bottle with a concentrated chlorine solution may also be used if the threads are clean. Then flush the tap in a wide open position for at least 5 minutes. If water accumulation is a problem around the base of the tap, use a hose to divert water away while flushing. Remove the hose and again clean the threads on the tap and briefly flush before sampling.

Sampling for Coliform Bacteria Analysis - Desirable Sampling Tap Characteristics:

1. The sampling tap is in a clean location.
2. The tap is in frequent use.
3. The flow of water from the tap is easily controlled.
4. A uniform, straight stream of water comes out of the tap.
5. The tap is located where it may be flushed as part of the sampling procedure.
6. The tap location is easily accessible.
7. The sample bottle may easily fit under the tap.
8. Cold water only, i.e., not from a tap that blends hot and cold water.

Sampling for Coliform Bacteria Analysis – Sampling Taps to Avoid, if Possible (from Bacteriological Sampling, 1988)

1. Taps with swivel/swing type spouts

2. Faucets with leaks around the valve stem.

3. Taps with leaks around the base of the spout.

4. Taps with aerators or other accessories (such as filters) attached to the spout, unless they are removed before sampling.

5. Taps located in areas that are not cleaned or maintained.

6. Taps that are subject to splash or contamination.

Example: Pot and pan washing sink in a restaurant kitchen or a janitor's mop sink.

7. Taps with threaded bibs.

8. Taps that do not have a uniform stream of water.

9. Mixing (hot and cold) faucets.

10. Frost free hydrants with buried stop and waste valves

11. Faucets that were recently installed or repaired, and have not yet been treated with chlorine.

Sampling Taps at the Pressure Tank.
Michigan's Well Construction Code <u>minimum</u> requirements for the sampling tap at the pressure tank are as follows:

1. Must be in a convenient location.
2. Must be installed at the pressure tank or as close to the well as possible.
3. Must be at least 8 inches above the floor.
4. Must be down turned.

However, it is suggested that the following design criteria also be considered to make the use of the sampling tap more practical:

1. The tap should terminate at least 18 inches above the floor. This allows for placing a 5 gallon bucket under the tap when flushing prior to sampling. This is particularly helpful in homes with a finished basement without a nearby floor drain.

2. Use a smooth bore sampling tap. This allows for a uniform stream of water.

3. Consider the installation of two taps. One is threaded to allow the draining of the pressure tank and distribution system with the use of a hose and one is unthreaded for use as a sampling tap.

Crawl Space Installation of Sampling Taps

Pressure tanks are sometimes installed in crawl spaces. A tap installed at a pressure tank located in a crawl space should not be used as a point to collect samples for coliform bacterial analysis. Crawl spaces are “confined spaces” and special precautions (in accordance with the Michigan Occupational Health Standards, Part 90 and Part 490) must be taken before entering.

For crawl space tank installations, it is suggested that a faucet be installed outside the crawlspace wall directly adjacent to the pressure tank. Although outside taps are not the best for sampling purposes, it can be easily flushed and is conveniently located. It is better than having the sampling tap in the crawl space. A tap should still be installed at the pressure tank in these cases to drain the pressure tank and/or distribution system.

This tap cannot be easily flushed, is not conveniently located, and is not in a clean area.

Coliform Bacteria Water Sample Collection Procedures

1. **Select the sampling location**

   The sampling location selected should reflect the quality of water coming from that portion of the water supply being evaluated. For example, if the well itself is being evaluated, do not use a sampling location out in the distribution system. Use the sampling tap closest to the wellhead or at the pressure tank.

   Review the sections on sampling locations and sample taps presented earlier.

2. **Aerators**

   Many taps on sinks have aerators on the end of the spout. Aerators break up the flow of water by allowing air bubbles to mix with the water. The air may “freshen” the water and increase the volume (not quantity) of the water as it leaves the tap. But should the aerators be left on, or taken off while sampling?

   ❖ If the purpose of the sampling is to evaluate what the user of the water supply may be exposed to during normal use, then the aerator should not be removed (i.e., routine monitoring). The user typically does not remove the aerator prior to getting a glass of water to drink.

❖ If the sample being collected is a follow up to an earlier positive sample, it is desirable to eliminate as many sources of potential contamination as possible. Removing the aerator eliminates one possible contaminant source.

If an aerator is removed, the end of the sampling tap/spout must be cleaned with an alcohol swab or a clean cloth soaked in a chlorine solution, and the tap then thoroughly flushed before sampling.

3. **Clean and disinfect the sampling tap.** Using an alcohol wipe or a clean cloth soaked with chlorine, wipe off the exterior surfaces at the tip (discharge point) of the sampling tap, with particular attention to cleaning any threads or other grooved or rough surfaces.

The use of heat to disinfect a sampling tap is not recommended. Heat may damage nonmetal components and the thin plating present on many fixtures. Sometimes it is difficult to distinguish a plastic faucet from a metallic faucet.

4. **Flush the sampling tap and distribution system.** Flush the distribution system by turning on faucets at the kitchen sink, bathroom sinks, bathtubs, and laundry sink, and flushing each toilet at least once. Leave these faucets running until after the water sample has been collected.

Turn on the tap selected for sampling, usually the kitchen sink, to the maximum extent possible (splash may be a problem and should be avoided), and let the water run for at least 5 minutes.

Flush for at least one pump cycle (i.e., the time from pump start to stop). For a conventional single family home this is usually about 5 to 10 gallons of water or at least 5 minutes of flushing time.

Flush until the water is as cold as it will get. This suggests that the water being delivered has not been in the pipes or storage tank for any extended length of time. Extending the flushing time and maximizing the flow of water during flushing, will reduce the possibility that the distribution system or sampling tap are the cause of a positive sample.

5. **Reduce the flow of water before collecting the sample.** Reduce the flow of water at the sampling tap to a steady stream with no splash occurring. This will allow for a controlled filling of the water sample container.

Leave other faucets running until samples have been collected.

6. **Collect the water sample.** Use only sterile containers specifically prepared and designated for collecting water samples for coliform bacteria analysis. If the cap of the sampling container is loose or dropped, or if the integrity of the sample container is in question, discard the sample container.

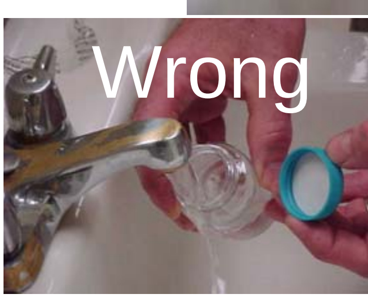
Chlorine residual is still present.

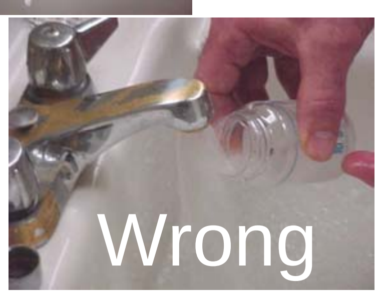
If the water supply system has been recently treated with chlorine, use a chlorine test kit to assure that no chlorine residual is present. If chlorine residual is present the water supply system needs further flushing before a sample is collected.

Do not rinse the sample container. The container is treated with sodium thiosulfate, which inactivates any chlorine which may still be present in the water.

Remove the seal and cap from the sample container and hold the cap in your hand, facing downward. Do not touch the rim or inside of the cap or sample container. Do not set the cap on any surface.

Collect the water sample immediately after removing the cap. Keep the stream of water from the tap completely inside the mouth of the sample container.





Fill the sample container to the designated 100 milliliter line. Do not allow the sample container to overflow.

Tightly recap the sample container immediately after collecting the water.

7. **Shake the sample container.** Gently and briefly shake the sample container to dissolve the sodium thiosulfate tablet or residue in the container, if present.

8. **Turn off all water faucets.**

9. **Clean and replace the aerators.**

10. **Complete the water sample report form.**

11. **Promptly mail or deliver the water sample to a state certified laboratory for analysis.**

Interpretation of the Results of Water Sample Analysis (Prepared for distribution by the Michigan Department of Environmental Quality Drinking Water Laboratory).
Bacteriological Analysis:
Evaluation of the bacteriological quality of drinking water is done using "coliform" testing. Coliform bacteria are found in the intestinal tract of warm-blooded animals, surface water, some soils, and decaying vegetation. Coliform bacteria are used as "indicator" organisms. If they are present, pathogenic, or disease-causing organisms, could be present. The Michigan Department of Environmental Quality (MDEQ) laboratory and many private laboratories use the "defined substrate method." A positive result may indicate that a water supply is not properly protected from contamination. The "defined substrate method" also detects E. coli, an organism that always originates from mammal or bird intestinal tracts. If E. coli is detected, it is more likely that the water supply may contain disease-causing organisms resulting from fecal contamination.

Result Code	This means:
ND	**"Not Detected"** – No coliform organisms were detected in the water sample. The sample met the state drinking water standard for bacteriological quality at the time of sampling. (Similar results may be reported as negative; absent; or zero, "0".)
POS	**"Positive"** – Coliform organisms were present in the water sample. Safety cannot be assured. Collection of a resample to confirm the original result is recommended. An investigation into the cause of the problem by a qualified individual is advised. (Similar results may be reported as present or any number from 1 to 200.)
EC-POS	**"E. coli detected"** – E. coli organisms were detected in the water sample. E. coli organisms are found in the intestines of warm-blooded animals, and as such, their presence in a water supply is considered an indication of sewage contamination. Precautions are recommended in the use of the water supply. These results are the same as fecal coliform positive; however, E. coli results indicate sewage contamination with more certainty. An investigation into the cause of the problem by a qualified individual is advised.
COMMENTS	Coliform organisms may die during sample holding time (time from collection to testing). The laboratory will comment that results may not be representative or valid if sample holding time is longer than 48 hours. The federal standard for a coliform holding time limit for public water supplies is 30 hours.

Michigan's Well Construction Code (MWCC) Requirements Relating to Well Disinfection

(Excerpts from Part 127, 1978 PA 368, as amended, and Administrative Rules)

MWCC Requirements on Well Development

R 325.1639 (1)(Rule 139) A water supply well that is installed in unconsolidated sand and gravel aquifers shall ordinarily be fitted with a screen that has openings which are properly sized so that the aquifer can be properly developed to produce sand-free water at the pumping rate of the permanent pump.

R 325.1639 (5)(Rule 139) A new, repaired, or reconditioned well shall be developed and pumped to waste at a pumping rate which equals or exceeds that of the permanent pump, until the water is as clear as is reasonably possible considering the groundwater conditions in the area. The permanent pump shall not be used to develop the well without the owner's consent.

MWCC Requirements on Flushing

R 325.1639 (5)(Rule 139) A new, repaired, or reconditioned well shall be developed and pumped to waste at a pumping rate which equals or exceeds that of the permanent pump, until the water is as clear as is reasonably possible considering the groundwater conditions in the area. The permanent pump shall not be used to develop the well without the owner's consent.

MWCC Requirements on Chlorination

R 325.1661, (Rule 161) Disinfection of well and pumping equipment
(4) After thoroughly pumping to waste pursuant to the provisions of R 325.1639(5), a well and pumping equipment shall be disinfected with chlorine that is applied to obtain a chlorine concentration and minimum contact period specified in table 5 in all parts of the water supply system before pumping the well to waste and flushing out the chlorine solution. A well drilling contractor or pump installer shall be responsible for chlorinating that portion of the water supply system on which work has been performed.

TABLE 5
MINIMUM CHLORINE CONCENTRATION AND CONTACT TIME

	Amount of Chlorine Added to 100 Gallons of Water		
Chlorine Concentration (Parts per Million)	Gallons of 5.25% Sodium Hypochlorite (Liquid Bleach)	Pounds of Dry Calcium Hypochlorite (Granular)	Minimum Contact Time
100 ppm	¼ gallon	0.14 lbs	10 hours
250 ppm	½ gallon	0.35 lbs	4 hours
500 ppm	1 gallon	0.70 lbs	2 hours
1000 ppm	2 gallons	1.40 lbs	1 hour

R 325.1639, Rule 139 (Excerpts)
(5) A new, repaired, or reconditioned well shall be developed and pumped to waste at a pumping rate which equals or exceeds that of the permanent pump, until the water is as clear as is reasonably possible considering the groundwater conditions in the area. The permanent pump shall not be used to develop the well without the owner's consent.

(8) Water that is used for drilling purposes, other than water from the well itself, shall be potable water that contains a free chlorine residual of not less than 10 parts per million at the time of use and shall be conveyed in containers that are clean and capable of being maintained in a clean condition. Surface water shall not be used for drilling purposes unless it is obtained from a municipal water supply system.

(9) When chlorine is placed into a water supply system pursuant to the provisions of R 325.1661 or when well rehabilitation chemicals are used, the well drilling contractor or pump installer shall provide notification to the well owner or building occupants or shall make the system inoperable during the treatment period.

R 325.1640, Rule 140

(2) After January 1, 1994, a person shall not use the following water well components unless they are in compliance with or surpass ANSI/NSF standard 14, 60, or 61, ASTM specification C 150, or section 10 of API specification 10, as adopted by reference in R 325.1610:

  (f) Chemicals that are used for the development, maintenance, treatment, disinfection, or rehabilitation of a water well, except for sodium hypochlorite or calcium hypochlorite.

Sodium hypochlorite and calcium hypochlorite are exempt from the certification requirement. Any other chemicals used in the treatment of a water supply must be certified.

<u>MWCC Requirements on Water Sampling</u>

R 325.1658, Rule 158 Pump Installation; sampling faucets

Provision shall be made for the collection of water samples by installing a down turned faucet, not less than 8 inches above the floor, in a convenient location at the pressure tank or as near to the well as possible.

R 325.1661, Rule 161 Disinfection of well and pumping equipment

(2) Before placing a new, repaired, or reconditioned water supply system into service, and after all traces of chlorine have been flushed out, 1 or more water samples shall be collected from the sampling faucet. Organisms of the coliform group shall not be present in the sample or samples.

(3) The water supply owner shall be responsible for collecting the water sample or shall arrange for the owner's designated representative to collect the sample. The well drilling contractor or pump installer shall notify the water supply owner of the owner's responsibility for collecting the water sample.

(4) A well driller or pump installer is not required to rechlorinate a well or pump as a result of water samples that are collected from a location other than the sampling faucet required pursuant to the provisions of R 325.1658.

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